Predicting mosquitoborne virus activity in California for decision support

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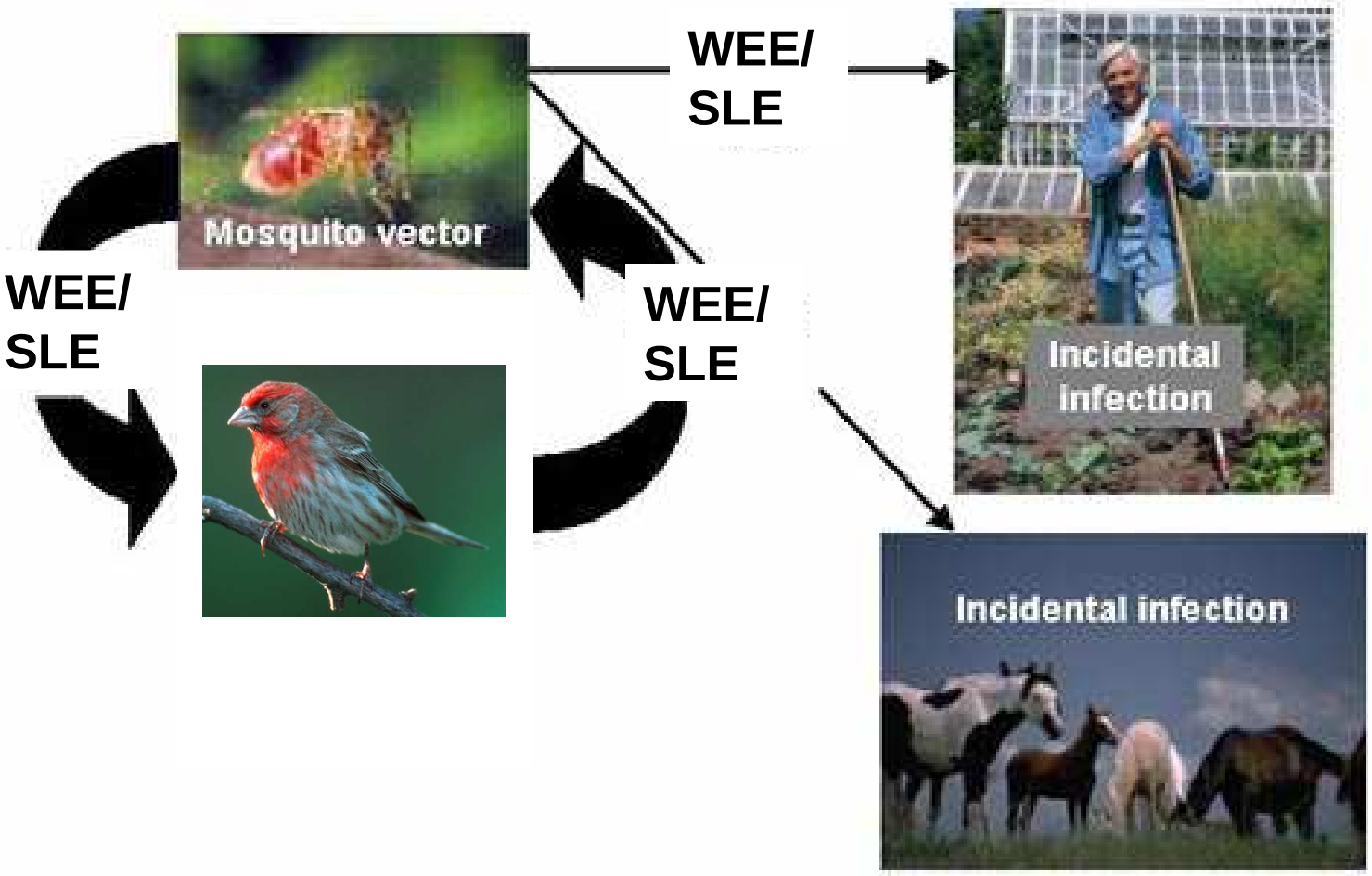
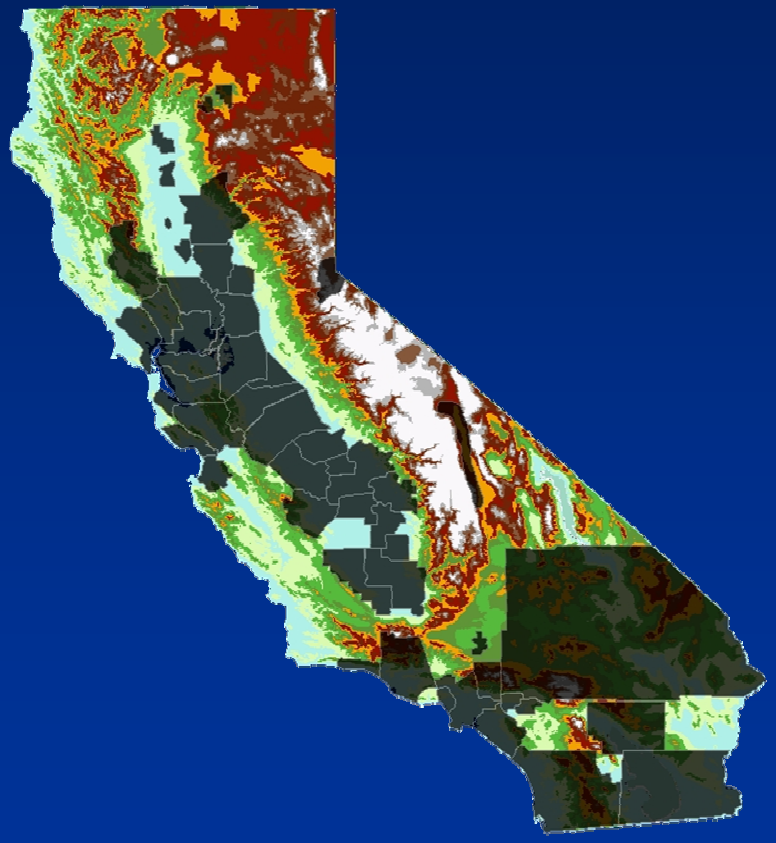
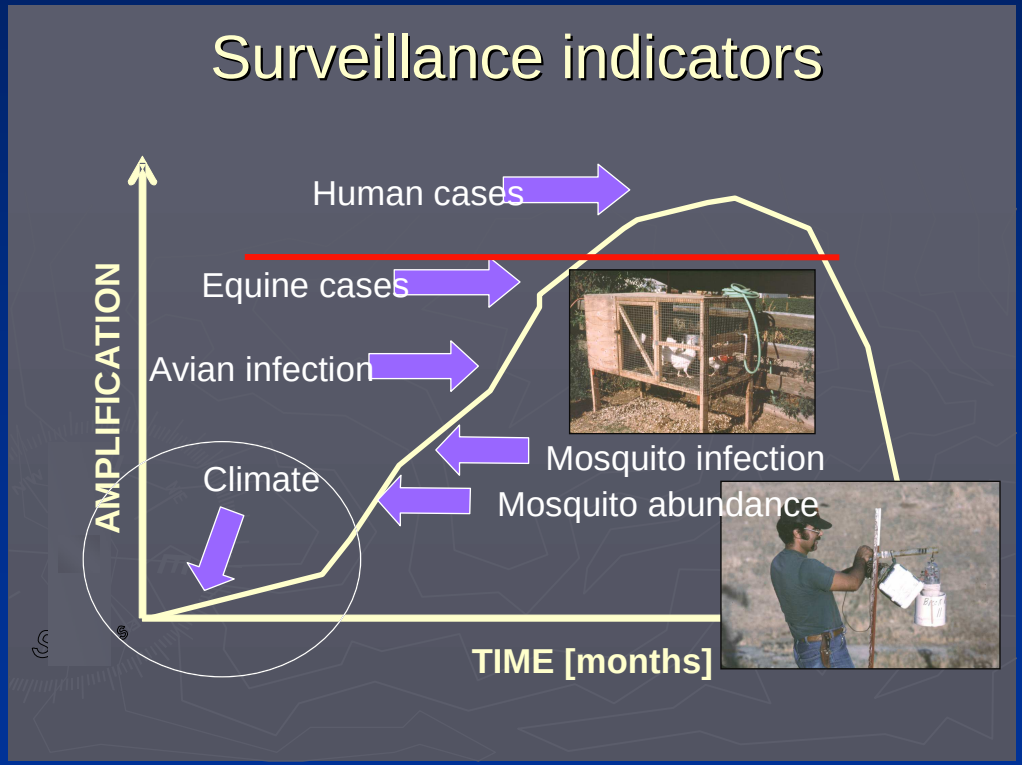
Western equine encephalomyelitis virus (WEE) and St. Louis encephalitis virus (SLE)



California WN, WEE, and SLE Surveillance System





CA Mosquitoborne Virus Surveillance and Response Plan

- Developed by California DHS to quantify the risk of WEE and SLE transmission to humans and provide guidelines for responses of vector control districts and public health agencies during periods of increased risk for virus activity
- Risk levels combine environmental, enzootic, and epidemiological factors
  - **Categories:**
    - **Normal Season**
    - **Emergency Planning**
    - **Epidemic**

Risk Values

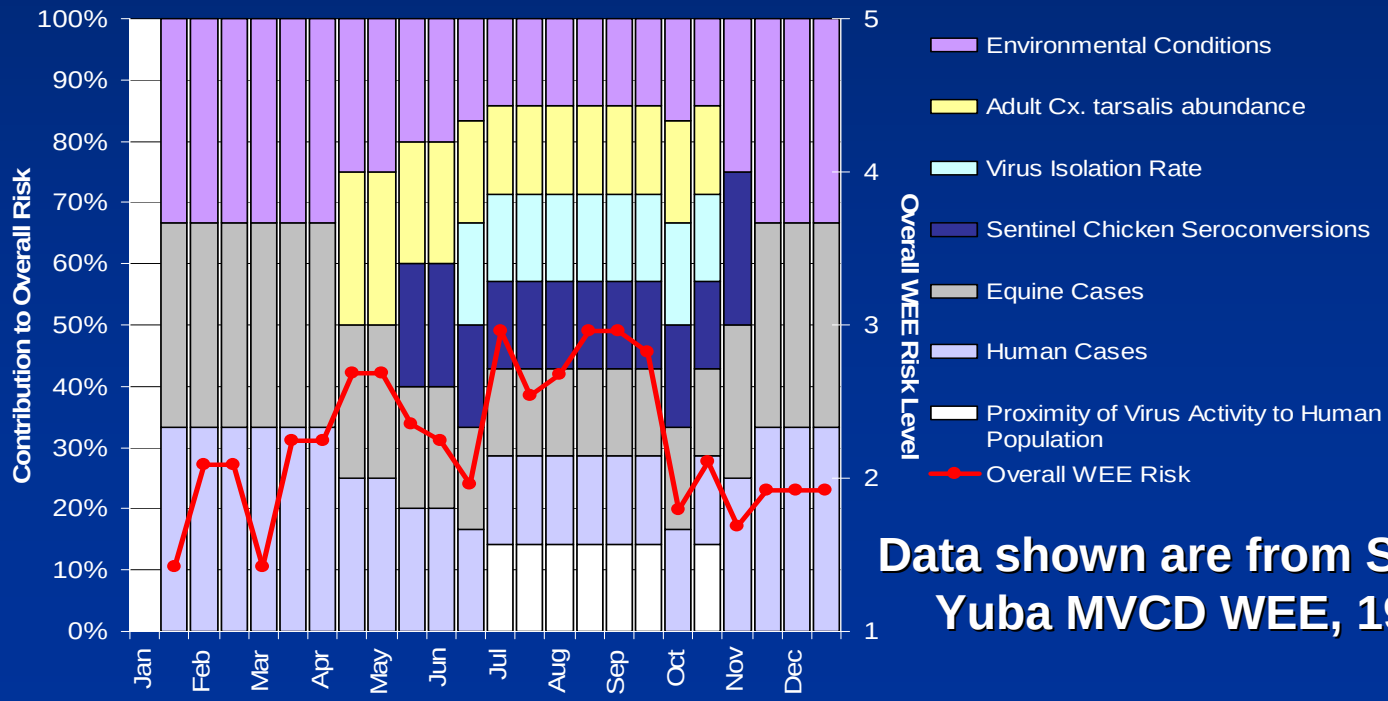
Risk Level	Env. Conditions			Adult mosquito abundance	Mosquito MIR/1,000	Chicken Seroconversions
	Rain	Runoff	Temp.			
1	Well Below Average			< 50% 10-yr. AVG	0	0 conversions
2	Below Average			50-90% 10-yr. AVG	0.1 - 1.0	1 conversion
3	Average			91-150% 10-yr. AVG	1.1 – 2.0	> 1 Pos. Flock Conversions/Pos. Flock <= 1
4	Above Average			151-300% 10-yr. AVG	2.1 – 5.0	Pos. Flocks > 1 1 < Conversions/Pos. Flock <= 3
5	Well Above Average			> 300% 10-yr. AVG	> 5.0	Pos. Flocks > 1 Conversions/Pos. Flock > 3

Risk Values

Risk Level	Equine Cases	Human Cases	Proximity of Virus Activity to Populated Areas
1	0 Statewide	0 Statewide	Remote Area
2			Rural Area
3	1 Statewide 0 Local	>= 1 Statewide 0 Local	Small Towns
4	1-2 Local		Suburban Area
5	>2 Local	>= 1 Local	Urban Area

CA Mosquitoborne Virus Surveillance and Response Plan

- Risk values (on a scale from 1-5) for all available individual factors are averaged to determine the overall risk for virus transmission to humans



Data shown are from Sutter-Yuba MVCD WEE, 1993

CA Mosquitoborne Virus Surveillance and Response Plan

- Strengths
  - Most calculations are straightforward
  - Portable, because it utilizes data that are accessible by all local agencies
- Weaknesses
  - All input variables are equally weighted, without regard to their importance
  - Model is underused because of data manipulations required for calculations
  - Does not account for water management

Objectives

- To use logistic regression to examine the effects of spring and summer mosquito abundance on the probability of detecting seroconversions for two arboviruses, WEE and SLE

- To identify other important predictors of WEE and SLE seroconversions (e.g., vector control district effort, meteorological factors such as precipitation and temperature, or the Southern Oscillation Index).

Logistic regression

The model:

$$\ln(p/[1-p]) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k$$

- Dichotomous outcome
- Some assumptions:
  - Linear relationship between predictor variables and log odds of the outcome
  - Additive effects of predictor variables on log odds scale

Study Areas


Sutter-Yuba MVCD
Kern MVCD
Coachella Valley MVCD
Sacramento-Yolo MVCD
Greater Los Angeles County VCD

Sentinel Chicken Seroconversions

Virus	Agency	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
WEE	COAV	■	■		■	■	■			■	■	■		■		■	■				■		12
	GRLA	N/A							■		■												2
	KERN	■	■												■	■	■						5
	SAYO					■						■	■	■	■	■							6
	SUYA	■			■	■						■	■	■	■	■	■						9

Virus	Agency	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Total
SLE	COAV	■	■	■	■			■	■	■	■	■	■	■	■	■		■	■	■	■	■	18
	GRLA	N/A	■	■	■	■	■	■	■		■	■			■		■						11
	KERN				■		■	■	■		■												5
	SAYO				■																		1
	SUYA																						0

Potential Predictors

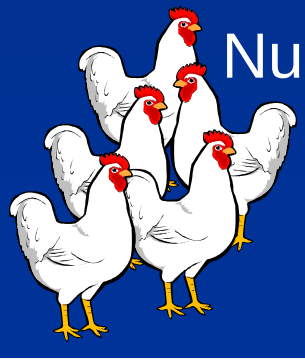
Southern Oscillation Index

Precipitation

Temperature

Adult Mosquito Vector Abundance

Agency Effort (Budget/Area)



Number of Flocks

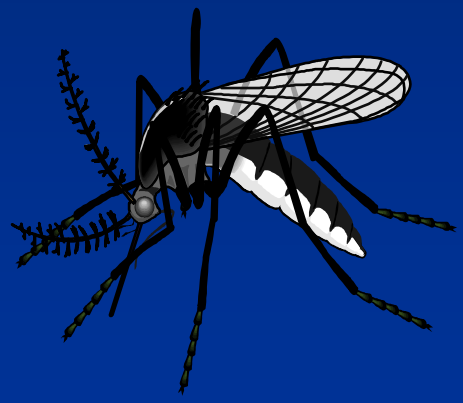
Logistic Regression Model

Pr (Sentinel Chicken Seroconversion)

Potential Predictors

- **<u>Mosquito abundance</u>** – based on numbers of females per NJ light trap-night, expressed as a percentage of the 21-year average, April-June, July-September, and monthly from April-October

  - *Culex tarsalis*
  - *Culex pipiens* complex
  - *Culex stigmatosoma*



Potential Predictors

- **Agency effects** – fixed, with Kern MVCD as the referent agency
- **Budget** – annual agency budget per square mile, adjusted to 2003 dollars
- **Number of flocks**

Potential Predictors

- **Temperature** – seasonal degree-day totals, January-March, April-June, July-September
- **Precipitation** – cumulative precipitation, October-March, January-March, March-May, and monthly from January-May
- **Southern Oscillation Index** – mean of monthly December-February standardized SOIs

Model Selection

- **Initial model included fixed effects for agency and a binary term for the previous year's seroconversions**
- **Other terms were added singly to these baseline models using a forward stepwise selection procedure to identify predictors for each virus separately**

Coefficients and Odds Ratios - WEE

Factor	βhat	Se (βhat)	95% CI	OR	95% CI	*p*-value*
Intercept	-3.75	0.90	(-5.54, -2.03)			<0.001
WEE-previous year	1.08	0.54	(0.014, 2.142)	2.94	(1.01, 8.51)	0.047
Coachella	2.07	0.86	(0.38, 3.76)	7.92	(1.47, 42.85)	0.016
Los Angeles	-1.96	1.26	(-4.43, 0.51)	0.14	(0.01, 1.67)	0.120
Sacramento-Yolo	-0.50	0.97	(-2.40, 1.41)	0.61	(0.09, 4.10)	0.610
Sutter-Yuba	-0.03	1.02	(-2.03, 1.97)	0.97	(0.13, 7.12)	0.975
Jan-Mar precipitation	0.06	0.026	(0.01, 0.11)	1.36 [a]	(1.05, 1.76)	0.018
Apr-Jun *Cx. tarsalis*	0.012	0.004	(0.004, 0.020)	1.13[b]	(1.04, 1.22)	0.003

* based on the Wald statistic (βhat/Se(βhat))

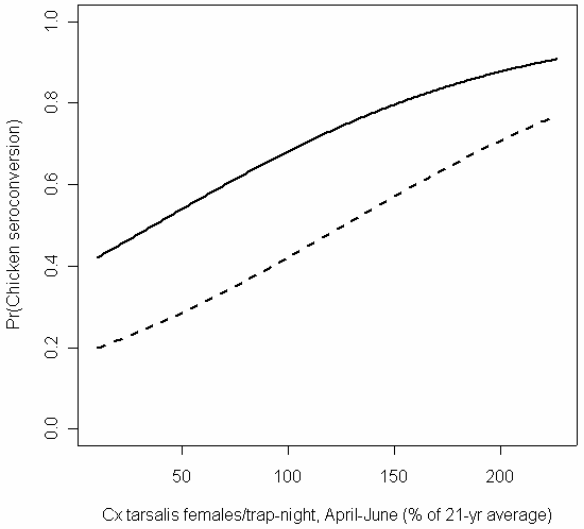
[a] based on an increase of 5 cm

[b] based on an increase of 10% in *Culex tarsalis* relative to the 21-year average

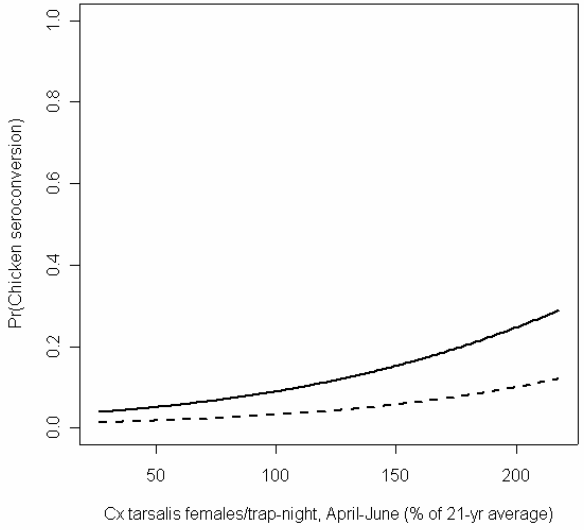
Model fits well based on Hosmer-Lemeshow GOF statistic (*p* = 0.448)

Pr (WEE seroconversion)

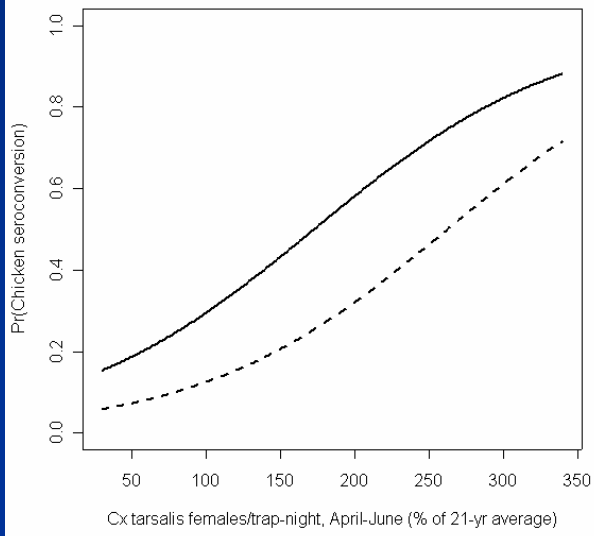
Coachella Valley MVCD



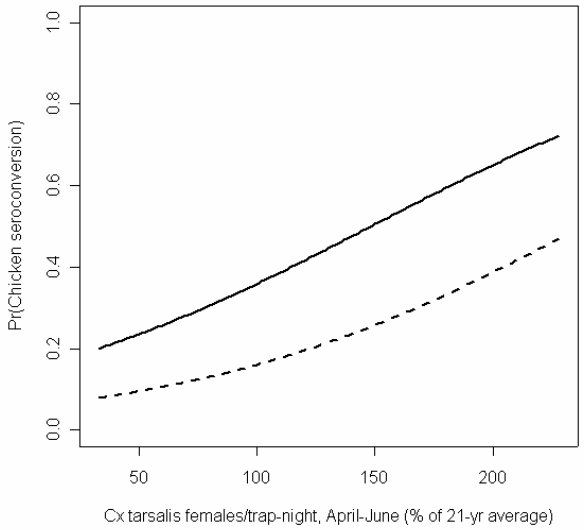
Greater Los Angeles VCD



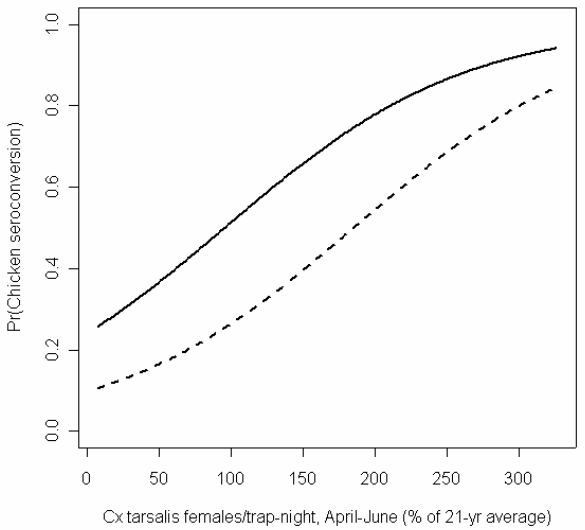
Kern MVCD



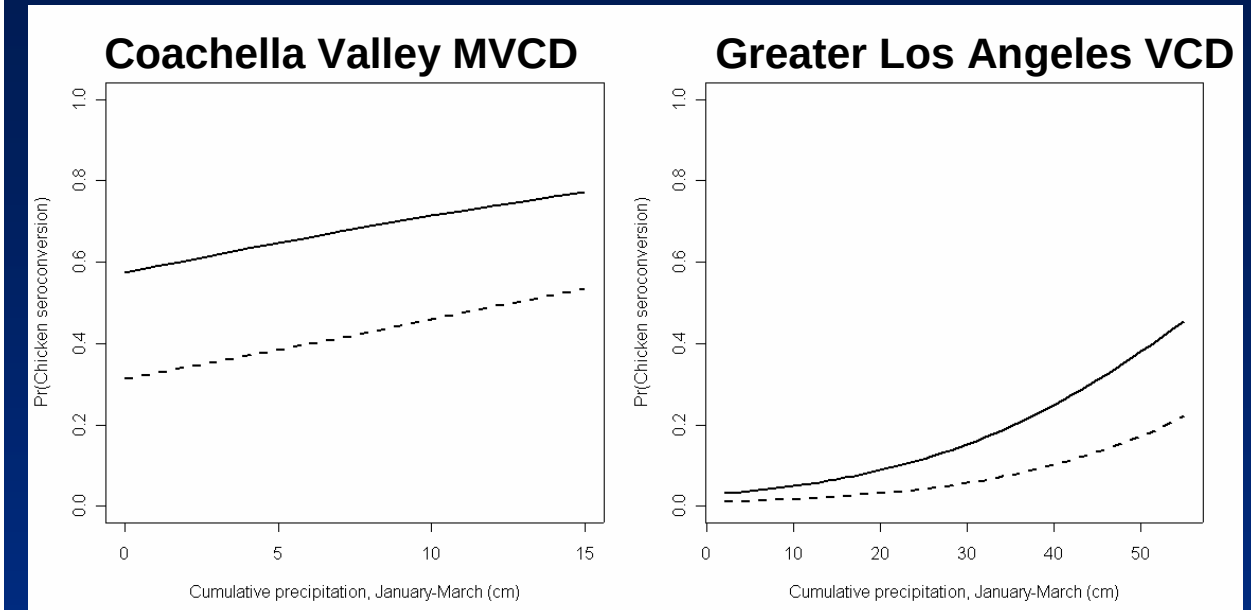
Sacramento-Yolo MVCD

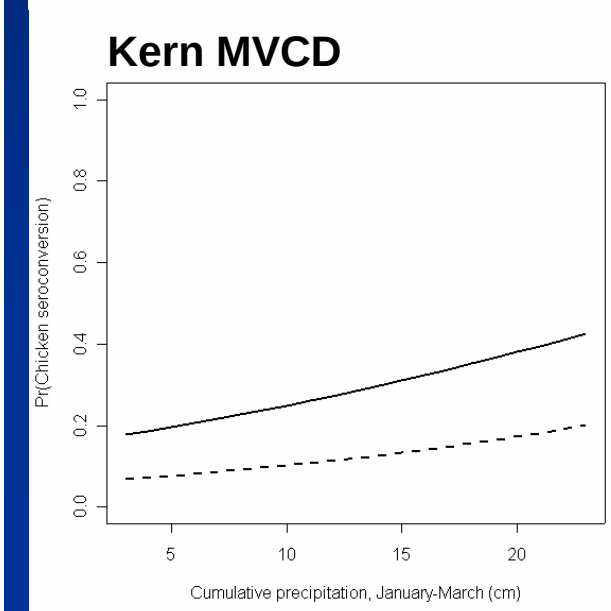


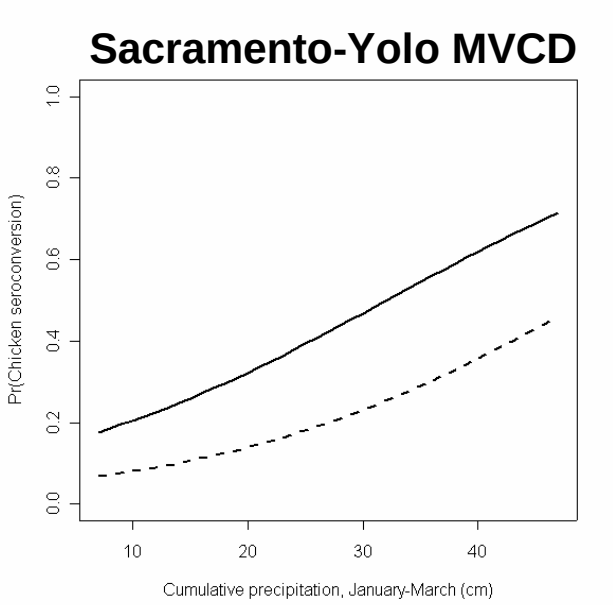
Sutter-Yuba MVCD

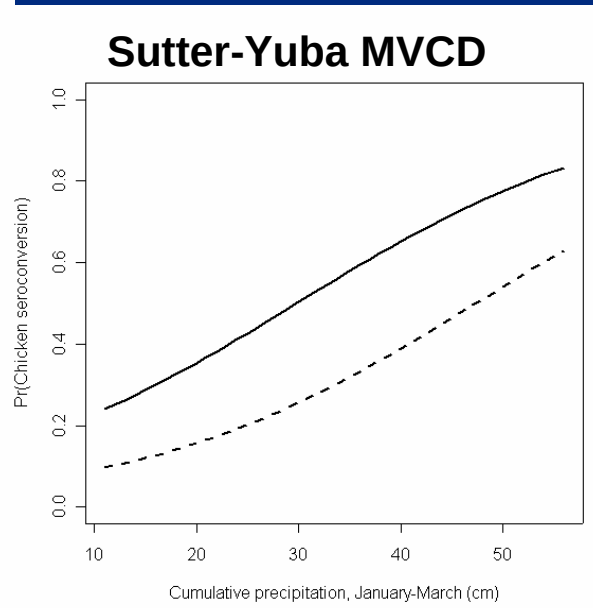


Pr (WEE seroconversion)

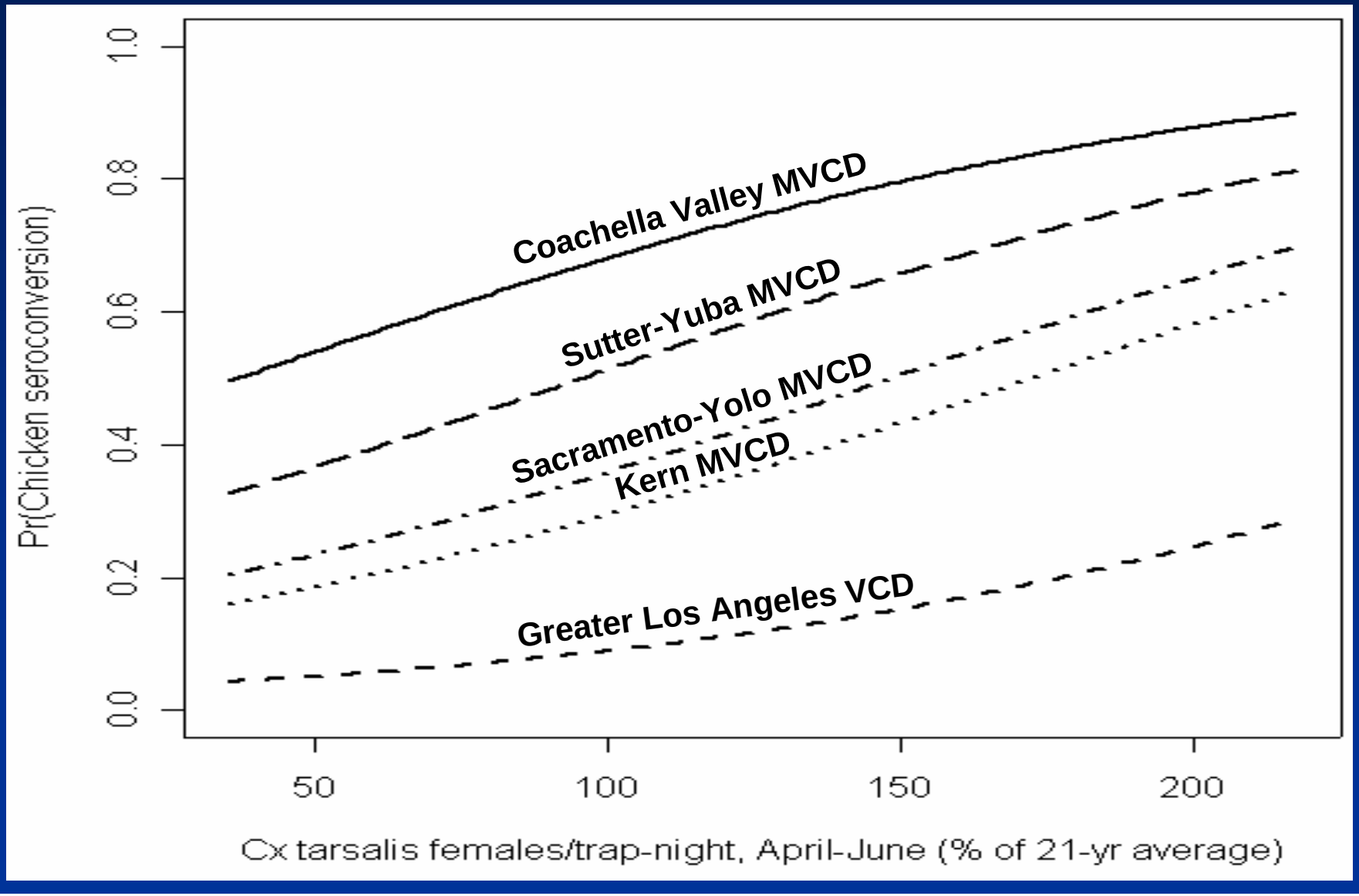








Pr (WEE seroconversion given seroconversion in previous year)



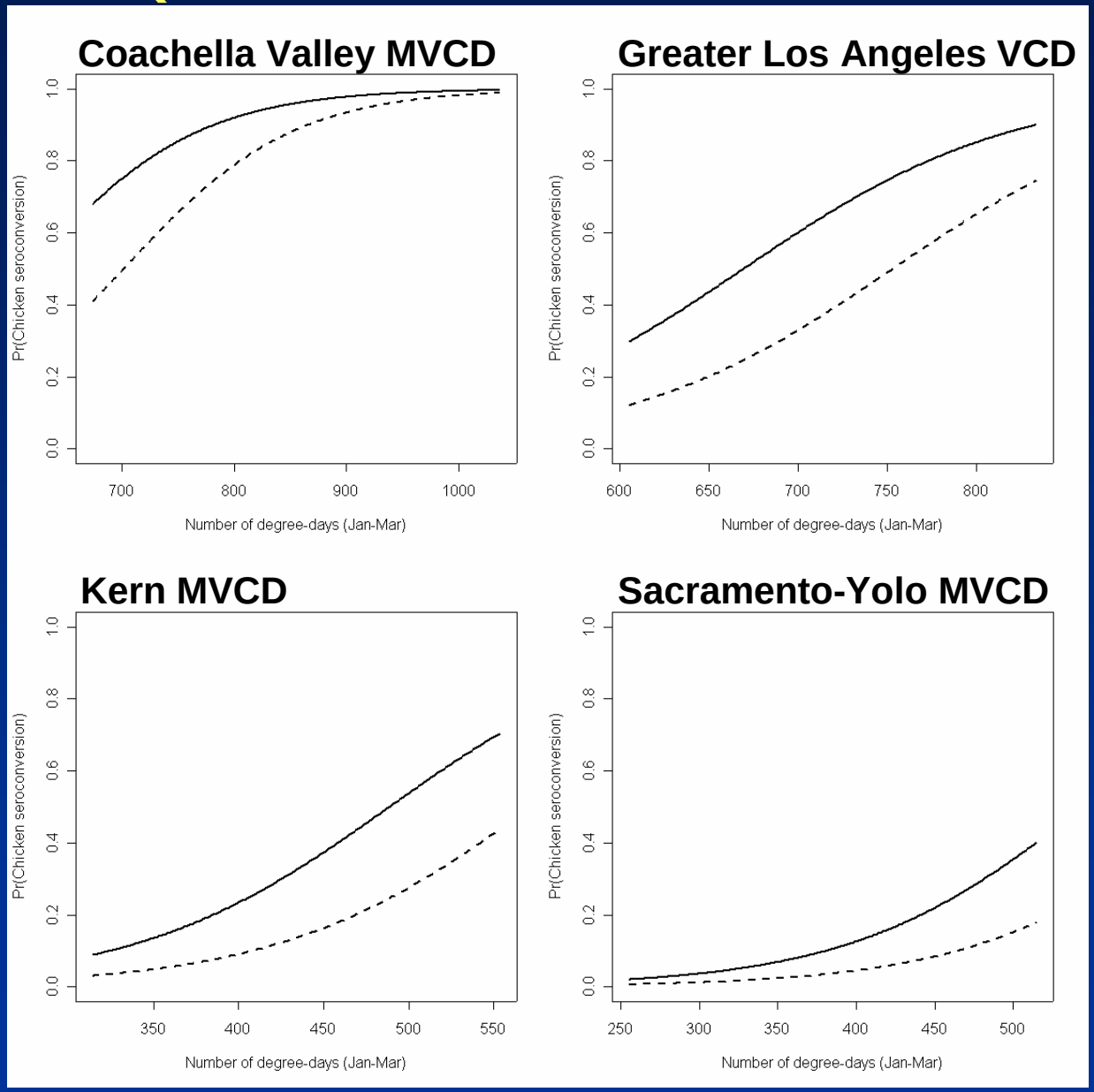
Coefficients and Odds Ratios - SLE

Factor	βhat	Se (βhat)	95% CI	OR	95% CI	*p*-value*
Intercept	-6.61	2.79	(-12.08,-1.14)			0.018
SLE-previous year	1.12	0.75	(-0.35,2.59)	3.06	(0.70, 13.34)	0.1364
Coachella	-1.77	2.16	(0.27, 14.47)	0.17	(0.00, 11.81)	0.413
Los Angeles	-2.26	1.66	(-7.36, 7.66)	0.10	(0.00, 2.71)	0.174
Sacramento-Yolo	-0.53	1.28	(-7.17, 13.13)	0.59	(0.05, 7.17)	0.677
Sutter-Yuba	-17.42	2277	(0.01, 0.05)	N/A	N/A	0.994
Jan-Mar deg-days	0.013	0.006	(-0.05, 0.11)	1.95 [a]	(1.10, 3.46)	0.023
Jul-Sep *Cx. tarsalis*	-0.012	0.006	(-0.20, 0.00)	0.88[b]	(0.78, 0.99)	0.040

* based on the Wald statistic (βhat/Se(βhat))
[a] based on an increase of 50 degree-days
[b] based on an increase of 10% in *Culex tarsalis* relative to the 21-year average

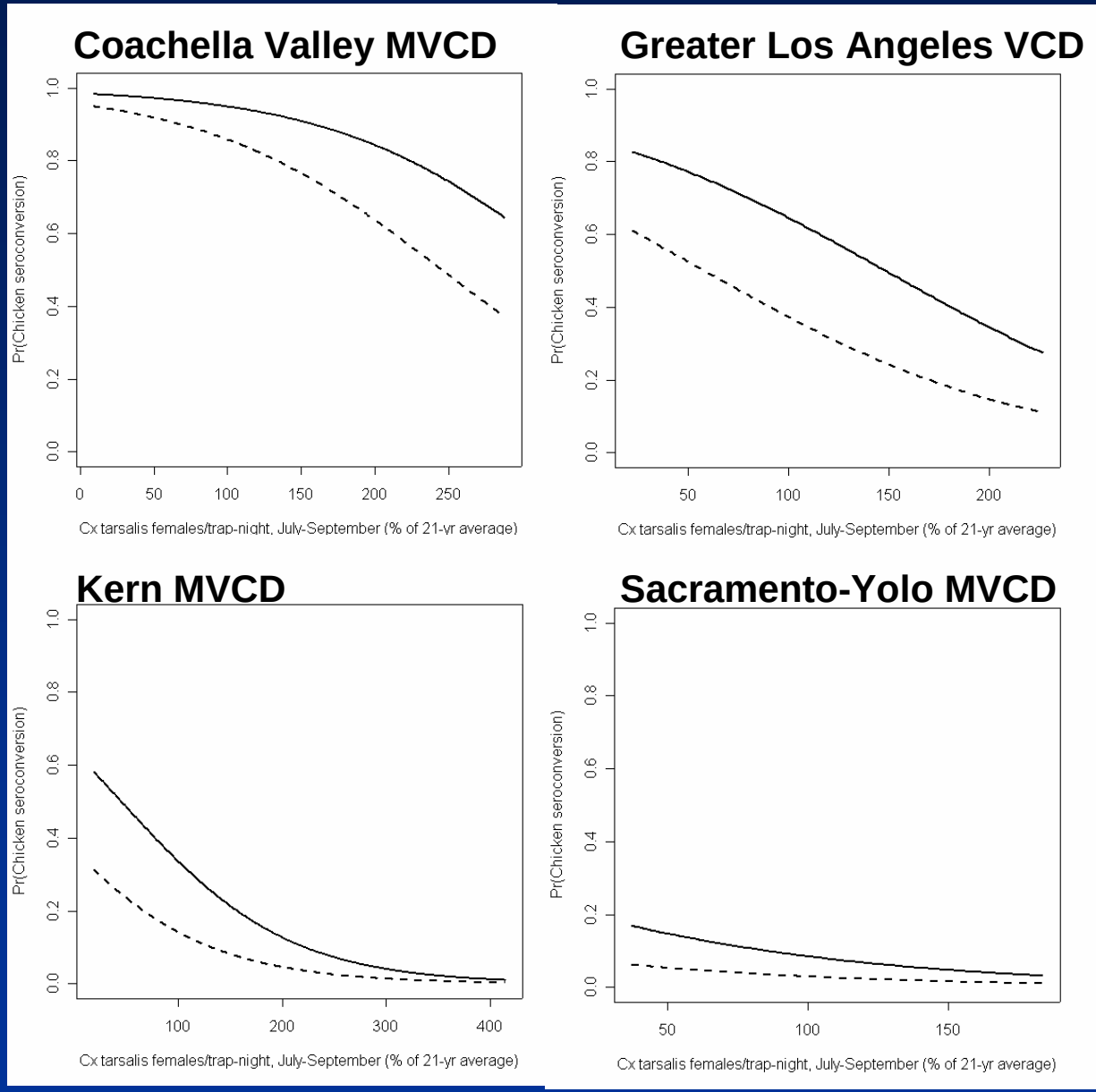
Model fits well based on Hosmer-Lemeshow GOF statistic (*p* = 0.743)

Pr (SLE seroconversion)



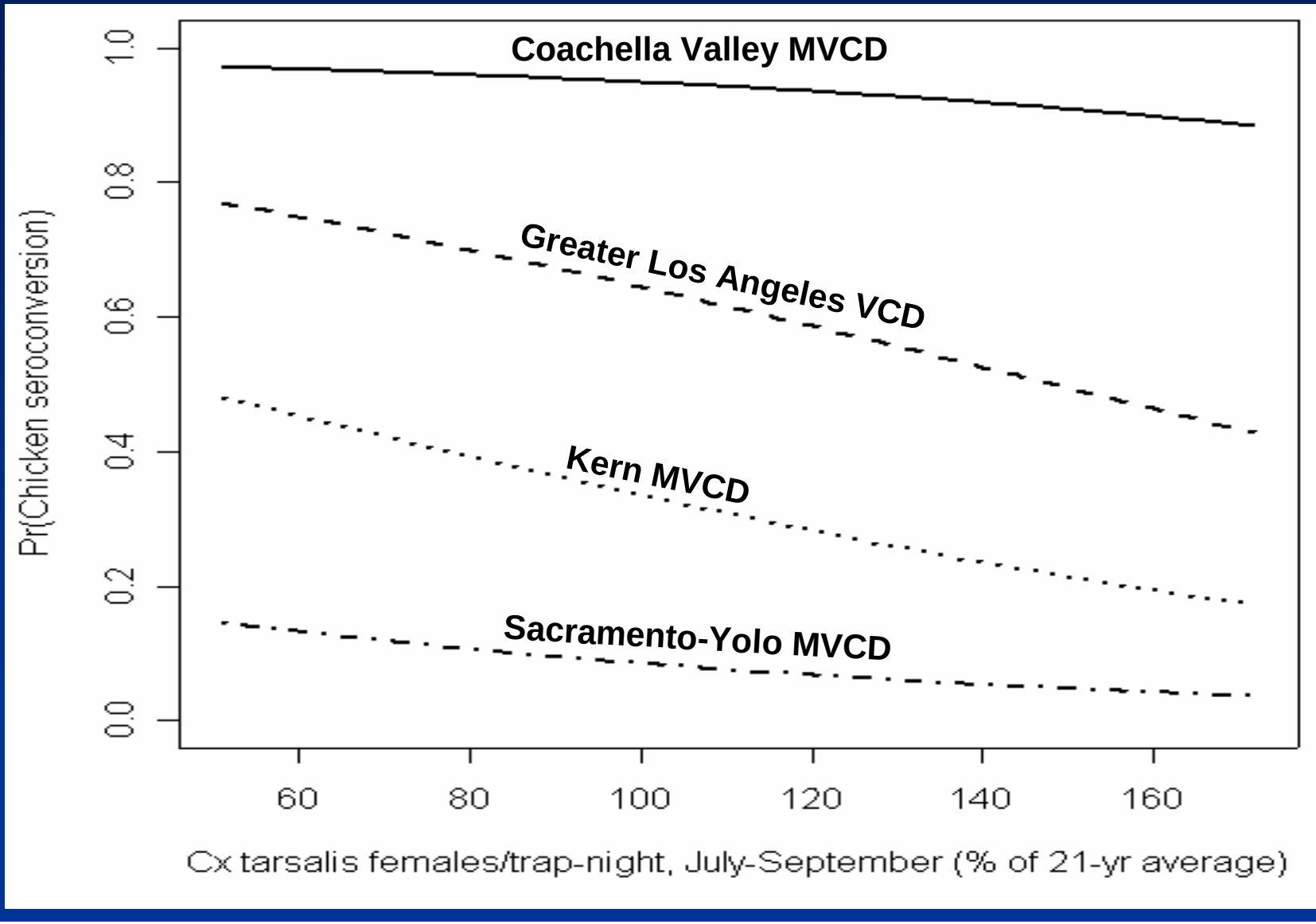
*** Probability of SLE seroconversion for Sutter-Yuba MVCD cannot be estimated**

Pr (SLE seroconversion)



*** Probability of SLE seroconversion for Sutter-Yuba MVCD cannot be estimated**

Pr (SLE seroconversion given seroconversion in previous year)



Conclusions

For WEE seroconversions:

- increased winter precipitation = increased risk
- increased spring *Cx. tarsalis* = increased risk

For SLE seroconversions:

- increased winter degree-days = increased risk
- increased summer *Cx. tarsalis* = decreased risk

Conclusions

- For WEE, a model including DJF SOI fit similarly compared to the chosen model including JFM precipitation, but precipitation was chosen because of interpretability
- Winter degree-days also were chosen instead of spring degree-days for SLE because the model fits were similar and the predictive value of the earlier variable was preferred
- Other factors did not significantly improve model fit based on LRT

Planned Analyses

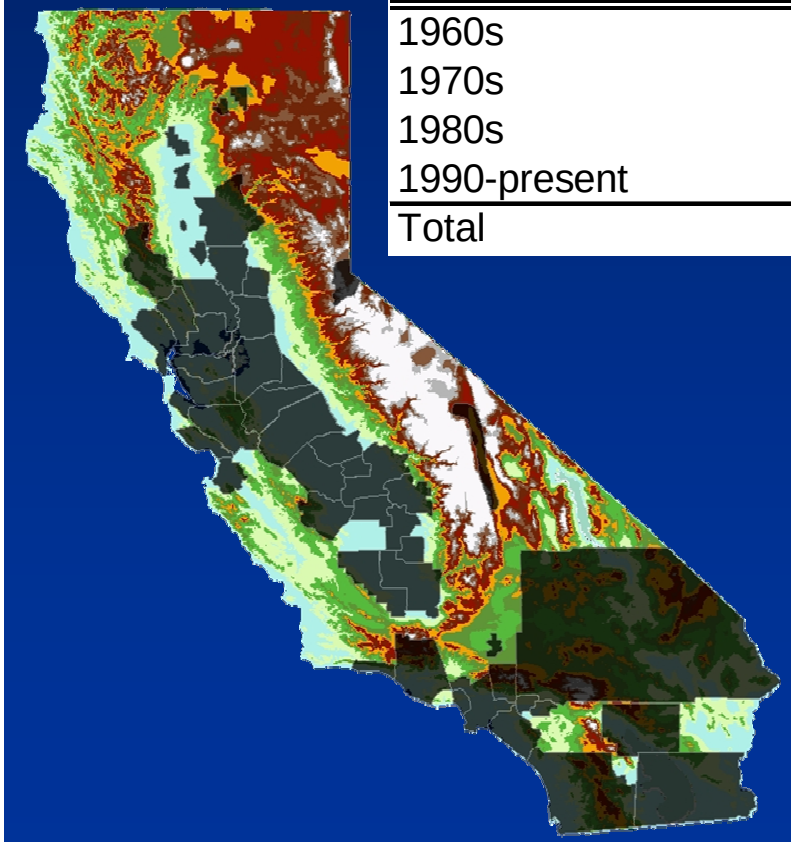
- District-level observations may mask associations at the individual flock level → additional study using site-by-site variables is needed
- Model inputs derived from remotely sensed imagery, such as NDVI and soil water content, will measure the vector habitat more directly, implicitly accounting for water management and other human intervention

Historical Dataset

Mosquito pools [1970-present]	
Cx. tarsalis	35,429
Cx. pipiens complex	8,325
Oc. melanimon	2,989
Total	46,743

Sentinel chicken sera

Decade	Agencies	Flocks	Sera
1960s	1	10	13,701
1970s	4	21	22,664
1980s	13	31	65,257
1990-present	49	206	196,850
Total			298,472

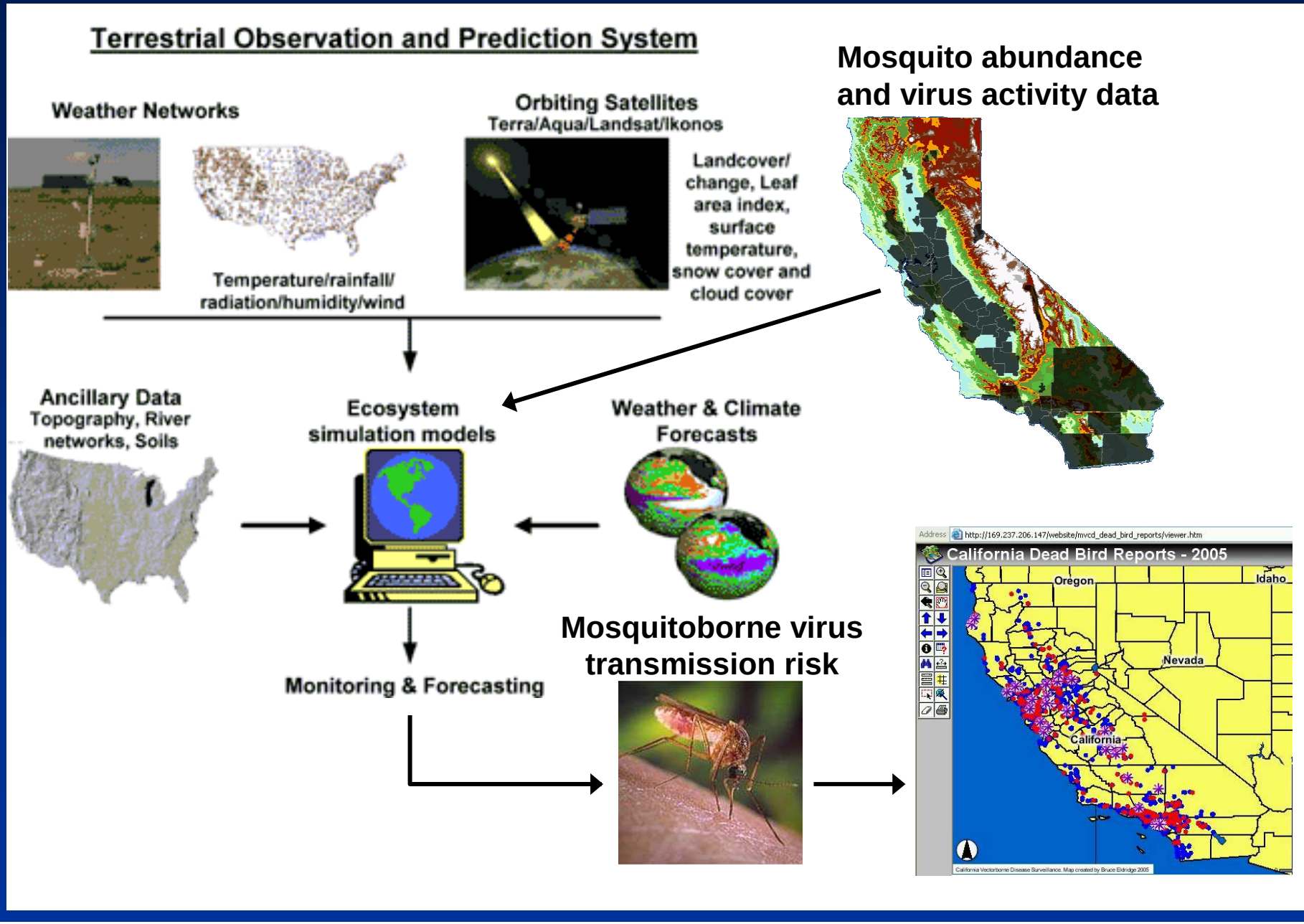


District	Trap Nights
Alameda County MAD	63,715
Antelope Valley MVCD	12,996
Burney Basin MAD	14,324
Butte County MVCD	107,324
Coachella Valley MVCD	158,763
Colusa MAD	10,282
Consolidated MAD	126,127
Contra Costa MVCD	137,352
Delano MAD	45,313
Delta VCD	92,565
East Side MAD	22,465
Fresno MVCD	34,966
Fresno Westside MAD	113,103
Glenn County MVCD	24,658
Greater Los Angeles County VCD	178,979
Imperial County Health	54,206
Kern MVCD	44,443
Kings MAD	31,576
Lake County VCD	13,926
Long Beach DHHS	4,529
Los Angeles County West VCD	18,000
Madera County MVCD	9,175
Marin-Sonoma MVCD	130,139
Merced County MAD	108,250
Moorpark City VC	26,056
North Salinas Valley MAD	104,664
Northwest MVCD	139,885
Orange County VCD	47,641
Placer MAD	3,874
Riverside County DEH	14,735
Sacramento-Yolo MVCD	150,121
San Bernardino County VCP	33,325
San Diego VSCD	53,251
San Gabriel Valley MVCD	532
San Joaquin County MVCD	204,698
San Mateo County MAD	140,022
Santa Barbara Coastal VCD	60,995
Santa Cruz County MVCD	11,255
Shasta MVCD	32,768
Solano County MAD	87,797
Sutter-Yuba MVCD	149,846
Tehama County MVCD	43,100
Tulare MAD	42,158
Turlock MAD	91,155
Ventura County DEH	57,254
West Side MVCD	22,449
West Valley MVCD	36,673

TOTAL: 3,111,430

Examples of TOPS products

Planned Application



Acknowledgments

- Data sources:
  - Kern County MVCD (Richard Takahashi), Sacramento-Yolo MVCD (Ken Boyce, Matt Farley, Rhonda Laffey), Sutter-Yuba MVCD (Debbie Lemenager), Greater Los Angeles County VCD (Minoo Madon, Paul O'Connor, Jacqueline Spoehel, Jennifer Wilson), Coachella Valley MVCD (Hugh Lothrop, Branka Lothrop, Arturo Gutierrez)
  - Weekly and annual arbovirus surveillance reports published by the Vector-borne Disease Section, CA Dept. of Health Services
  - Proceedings and Papers of the Annual Conferences of the Mosquito and Vector Control Association of California.
  - Reeves, W.C. 1990. Epidemiology and Control of Mosquito-Borne Arboviruses in California, 1943-1987. California Mosquito and Vector Control Association, Sacramento, CA.
- Funding Source: Climate Variability and Human Health, NOAA - Office of Global Programs.